

A Proposed Modification of the Bridge Gross Weight Formula

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A study was conducted using 201 different truck configurations and the entire bridge system of one state to develop a proposed modification of the current Bridge Gross Weight Formula. A new proposed formula is presented that minimizes the concerns for long trucks with a large number of axles. The proposed formula is less sensitive to axle group length and the number of axles than the current bridge formula.

STATEMENT OF PROBLEM

The FHWA (1) developed a bridge formula to estimate the "equivalent" load of a generic truck. This formula has worked very well for truck configurations using the nation's highways at that time. The generic truck was broken into groups of axles and the allowable weight for each group is calculated by the formula:

$$\text{Group}(N) = 500 [\text{LN}/(N-1) + 12N + 36] \quad (1)$$

Where

L = Length of group

N = Number of axles in group.

After the allowable weight is calculated for each axle group, the allowable weight for the vehicle is the sum of the allowable weights for each axle group. This equation requires numerous calculations depending upon the configuration of the vehicle.

Numerous researchers (2,3,4,5) observed the overall length of many trucks had significantly increased since the original bridge formula was developed. They also observed that the number of axles has also increased significantly. Both factors allow the trucking industry to significantly increase the allowable weight carried by long trucks. For states that use the original bridge formula to make permit decisions, there has been considerable concern on the impact these long trucks have on existing bridges.

The objective of this paper is to present the results of a study considering 201 different truck configurations on all bridges of a given state highway system. A total of 1,178 bridges were considered in the study. To aid in the study, an object oriented computer program was developed. A brief description of this algorithm will also be presented.

STUDY TRUCK CONFIGURATIONS

The 201 truck configurations considered in this study can be broken down into three classifications. The first classification, straight trucks, contains eight straight trucks with a single front axle and a combination of drive axles. The total number of axles ranges from 2 to 6 axles and the overall length of the trucks ranges from 12 to 45 feet. The

second classification of trucks, combination trucks, consists of a straight truck plus a trailer, or "pup," with a towbar. Fifty-six (56) different combination truck configurations were considered. Their length varies from 36 to 74 feet and each has between 4 and 16 axles. The final classification of trucks, triples, consists of a semi-tractor that tows two trailers in series. A total of 135 triple configurations were considered. Their length varies from 86 to 100.5 feet, and they have between 6 and 17 axles. A detailed description of each truck configuration can be found in Reference 6.

The distribution of weights between axles was determined by limiting single and tandem axle weights to 20,000 and 34,000 pounds respectively. The maximum axle weight for each axle group with three or more axles was calculated using the existing bridge formula. The percentage of total overall vehicle weight on each axle was calculated based on the allowable weight assigned to each axle of an axle group divided by the sum of axle group weights. In reality, the sum of the axle group weights is generally not the allowable weight for the vehicle but was used here to calculate a percentage of total weight for each axle.

BRIDGE DATA

While the author has received BARS data from two different states, the data used to modify the existing bridge formula came from only one state. In each case, the number of spans, total bridge length, length of each span and connectivity between adjacent spans was found in the data. A bridge operating rating, usually for an HS truck, was also available. With the operating rating of the rating HS vehicle and bridge geometry known, the envelope of allowable live load moments and shears was calculated at critical points along the bridge.

For the development of the modified bridge formula study, data for 1,178 bridges was considered. Posted bridges were not considered in the analysis because most states do not allow permitted trucks to travel over posted bridges.

BRIDGE LOAD RATING SOFTWARE

A bridge load rating program, PBRat, was developed, in Visual C++, using object-oriented programming techniques. With this technique, three objects were developed. One describes the bridge, another describes the truck, and the last one describes the influence line coefficients. Thus, the number of spans, length of each span, etc. became properties of the bridge object.

This approach to software development has proved to be very successful. On 200 MHz microcomputers, approximately 1,000 bridges per second per rating vehicle axle were analyzed. Thus, all

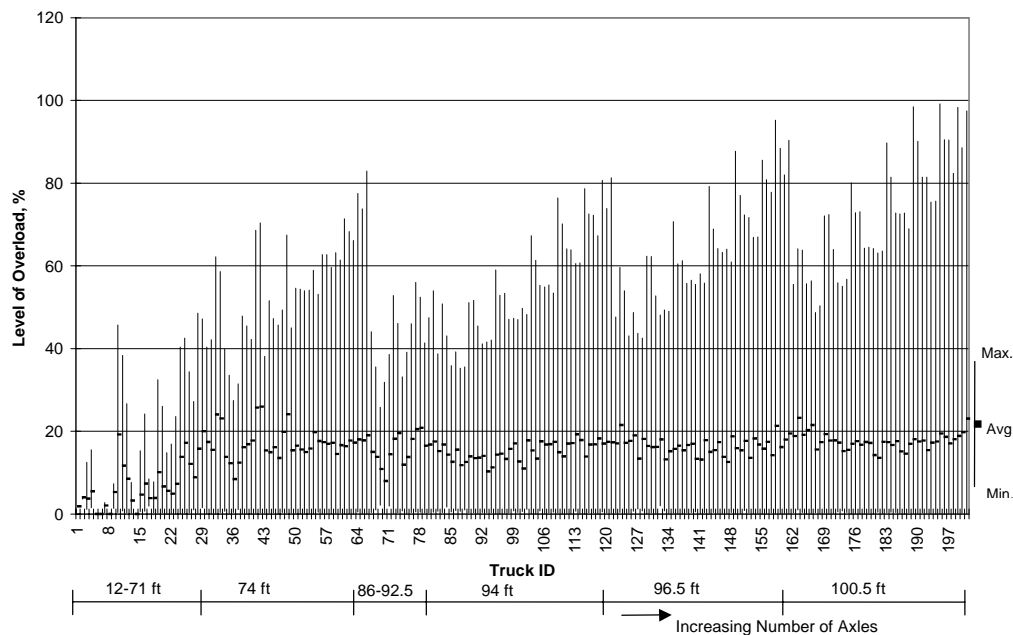


FIGURE 1 Degree of overloading using current bridge gross weight formula

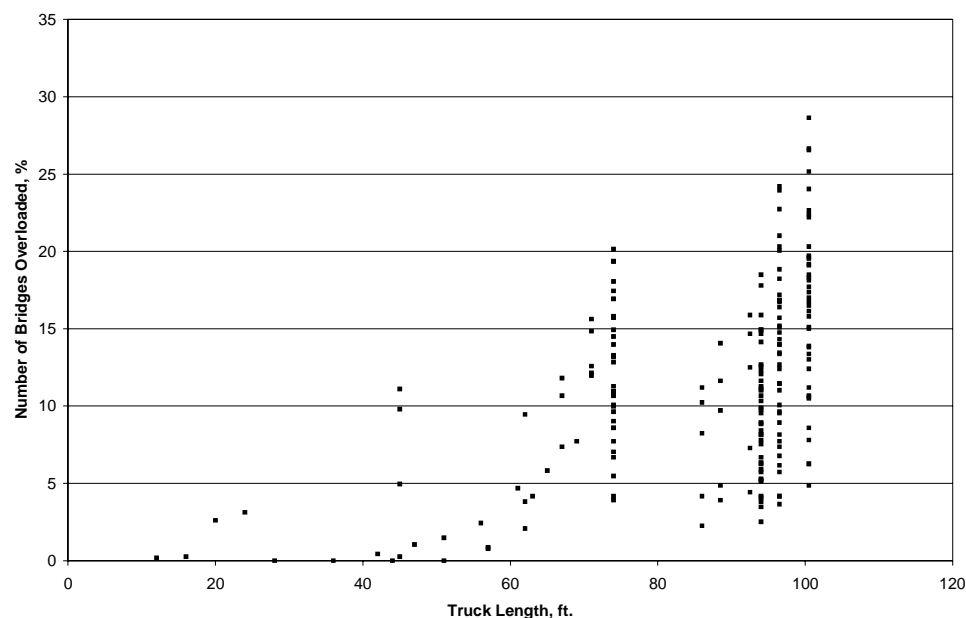


FIGURE 2 Number of bridges overloaded using current bridge gross weight formula

bridges on a system with 4,000 bridges could be load rated in less than a minute for a 17 axle permit truck.

RESULTS OF ANALYSIS USING THE CURRENT BRIDGE FORMULA

As PBRat analyzed the 1,178 bridges for the 201 truck configurations, the allowable truck weight, based on PBRat, was compared to the allowable load, based on the current bridge gross weight formula. The level of overload, the ratio of the actual allowable load from the current bridge formula, and the allowable load from PBRat were

calculated as a percentage. In Figure 1, the maximum, minimum, and average level of overloaded was shown to increase as the length of the truck increased and as the number of truck axles increased. The level of overloading approached 100% (double the operating capacity of the bridge) for the very long trucks with large number of axles.

The number of bridges overloaded using the current bridge gross weight formula was also plotted as function of truck length in Figure 2. Again, the number of bridges overloaded was found to increase as the length of the truck increased. When the number of bridges overloaded as a function of the number of axles, similar behavior was observed. When the current bridge gross weight formula is used to evaluate today's longer vehicles with many axles, it tends to

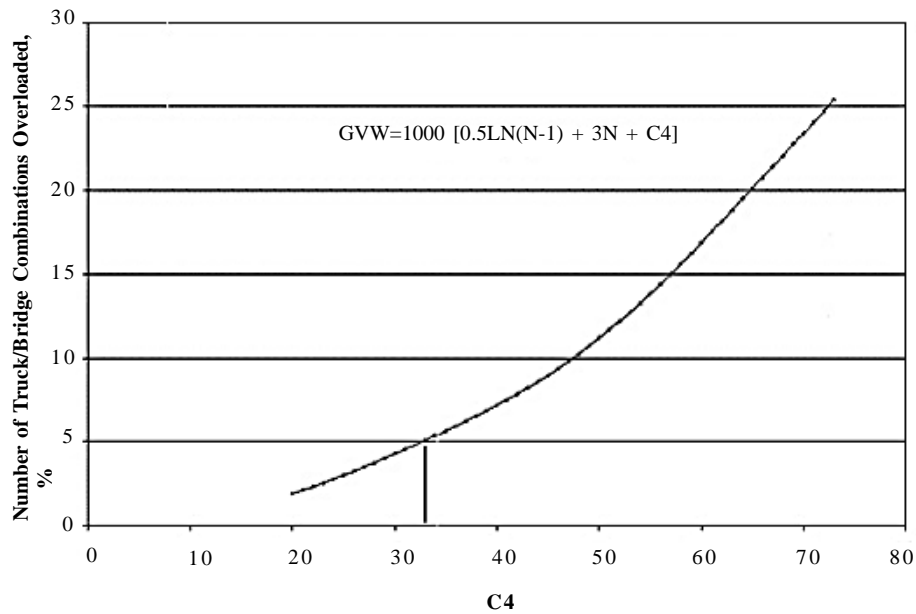


FIGURE 3 Number of overloaded bridges (%) as a function of C_4

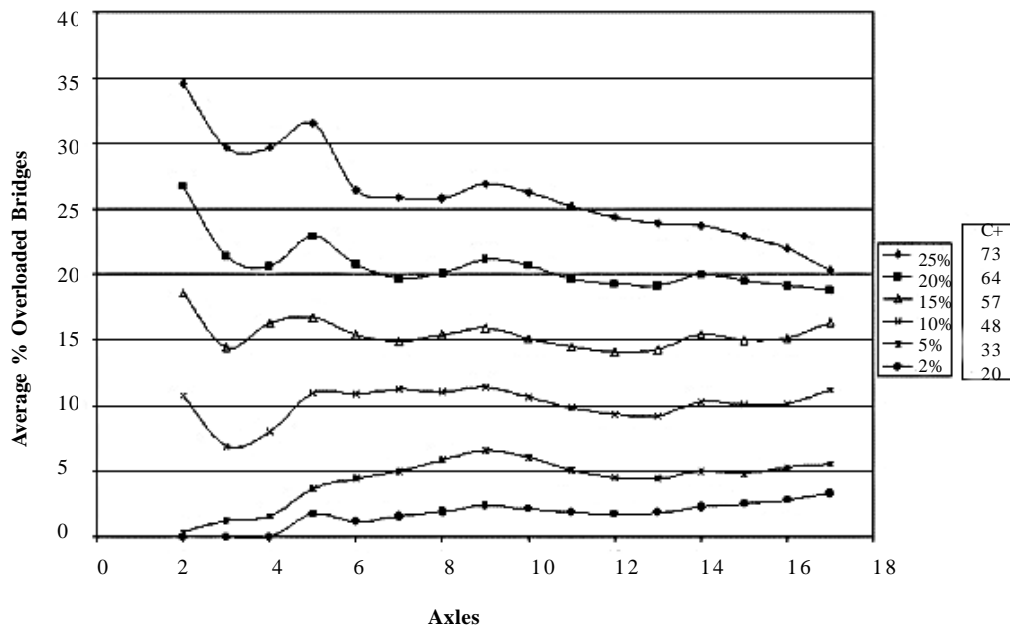


FIGURE 4 Average number of bridges overloaded (%) for various values of C_4

allow more weight, therefore more bridges are loaded beyond their operating capacity.

PROPOSED MODIFIED BRIDGE GROSS WEIGHT FORMULA

Several forms for a modified bridge formula were tested, including the Texas Transportation Institute (TTI) formula (7). However, the generic form of the one eventually selected is:

$$W = 1000 [C_1 LN/(N+C_2) + C_3 N + C_4] \quad (2)$$

Where

L = Length in feet
N = Number of axles

C_1 - C_4 = Constants

W = Gross weight in pounds.

A study was conducted to determine the optimum value for the constants C_1 through C_4 . After careful study, the best values for C_1 through C_3 were 0.5, -1, and 3, respectively. In each case, the number of overloaded bridges was nearly constant when plotted against the number of axles. Thus, the form of the proposed modified bridge formula becomes

$$W = 1000 [0.5LN/(N-1) + 3N + C_4] \quad (3)$$

Where

L = Length in feet
N = Number of axles
 C_4 = Constant for overloading
W = Gross weight in pounds.

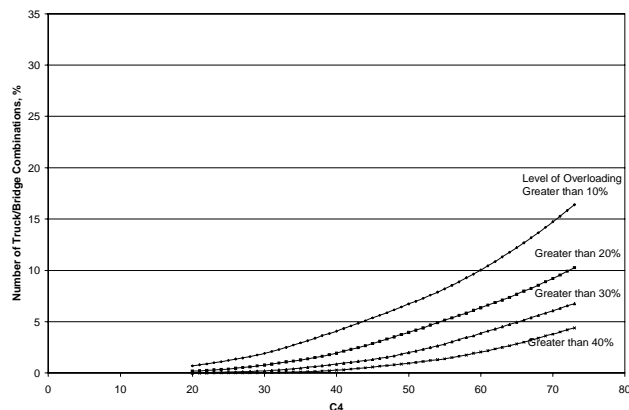


FIGURE 5 Number of truck/bridge combinations overloaded greater than 10, 20, 30 and 40 percent

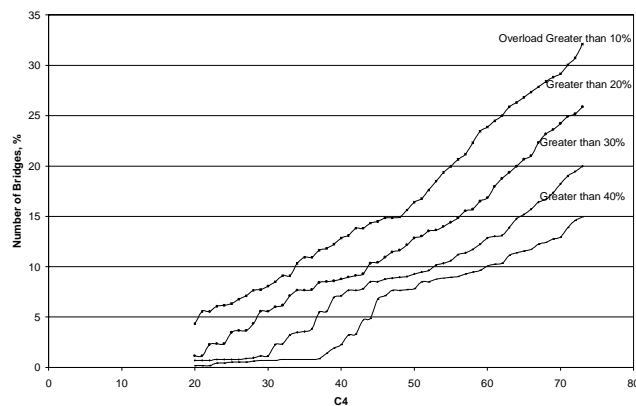


FIGURE 6 Number of bridges overloaded by 10, 20, 30 and 40 percent by the worst truck

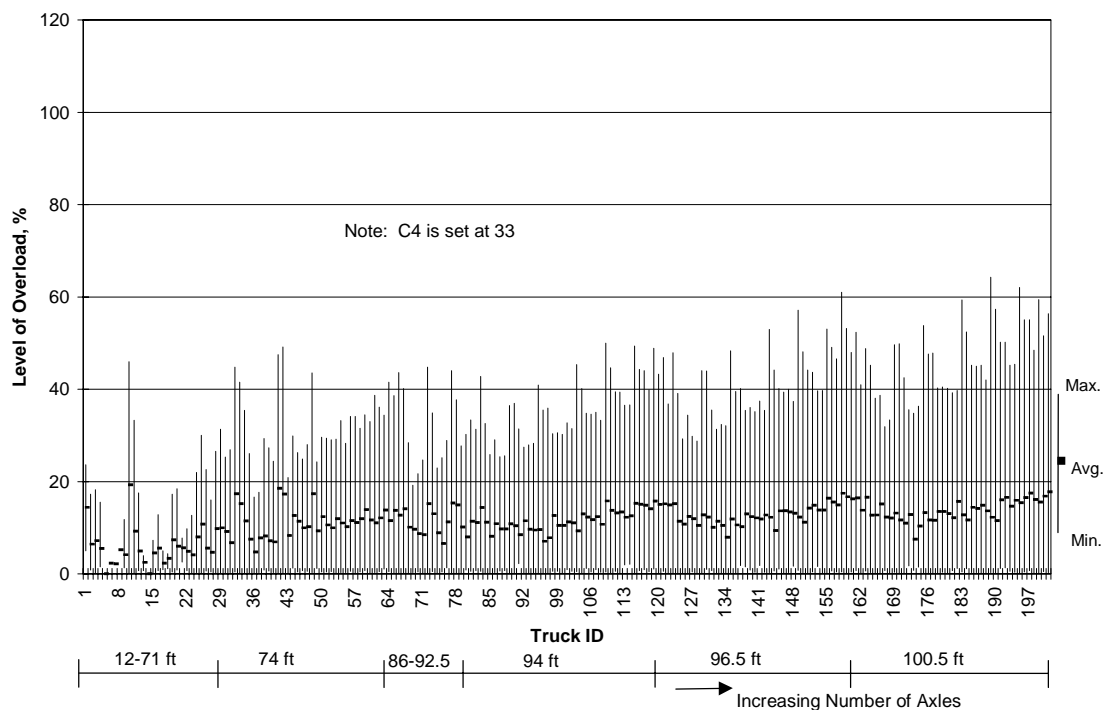


FIGURE 7 Level of overloading of bridges using modified bridge weight formula

To help agencies assign the proper value of C_4 to the formula, the chart in Figure 3 was developed. In Figure 4, the average percentage of overloaded bridges is plotted as a function of C_4 . As noted in the figure, if the agency decided that it was appropriate to overload approximately 5% of its bridges, the value of C_4 would be set to 33.

Figure 3 allows one to predict the number of bridges for the entire system overloaded for various values of C_4 ; it does not measure the number of bridges for each truck configuration with the same number of axles. The results of this study are shown in Figure 4. As seen in Figure 4, the average degree of overload is approximately constant with the number of truck axles.

While Figures 3 and 4 are helpful in setting the value for C_4 , additional information is useful. For example, in Figures 5 and

6, the number of truck/bridge combinations or bridges that were overloaded by a known percentage for all truck/bridge combinations or the worst truck are shown as a function of the value C_4 .

If one assumes that it is acceptable to overload 5 percent ($C_4 = 33$) of the bridges in a system, the level of overload is presented in Figure 7 for all bridges in the system. When compared to Figure 1 using the current bridge formula, one makes several interesting observations. For example, the impact of truck length is greatly reduced and the impact of axle length is also reduced. Also, the maximum level of overload was reduced from nearly 100 percent to only 64 percent. In Figure 8, the number of bridges overloaded using a $C_4 = 33$ is also presented. Again, in this figure, the impact of truck length is minimized and the number of bridges overloaded is reduced for all truck lengths.

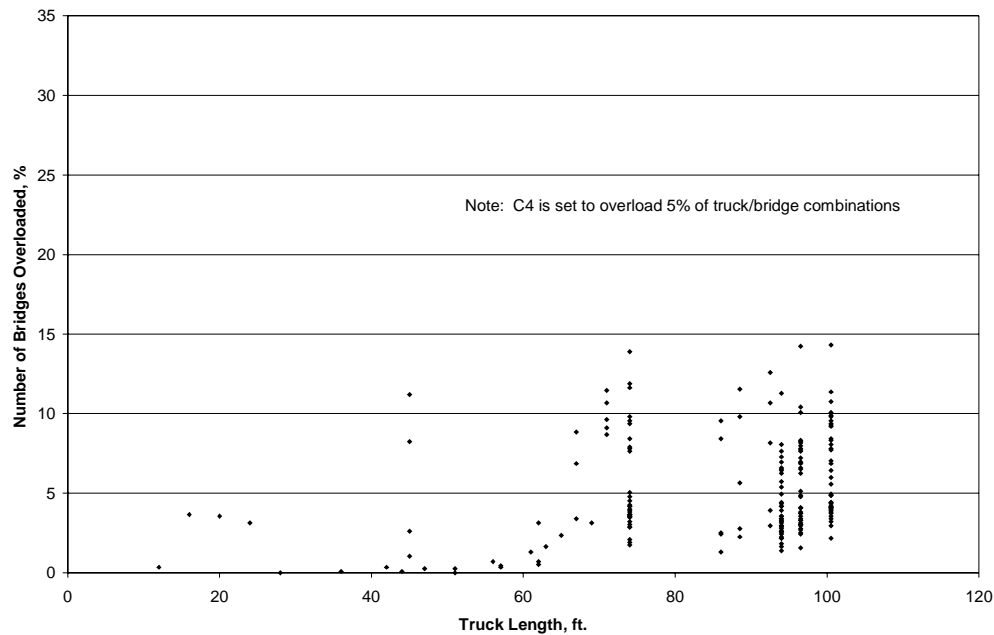


FIGURE 8 Number of bridges overloaded considering all trucks and modified bridge gross weight formula

IMPACT OF MODIFIED BRIDGE FORMULA

With the development of the proposed modified bridge formula, the user can control the conservatism used in adopting the variable C_4 . In general, the modified formula reduces the allowable loads of trucks with large overall lengths and a large number of axles. At a value of 33, the modified formula reduces the long group lengths with large number of axles approximately 30,000 pounds. However, for the shorter trucks, the allowable gross weight is increased using the proposed modified formula.

SUMMARY AND CONCLUSIONS

Over 231,000 truck/bridge combinations were considered in this study to develop a proposed modified bridge gross weight formula to estimate the allowable load for a generic truck configuration. A formula is proposed that minimizes the impact of truck length and number of axles on the overall allowable gross vehicle weight. The degree of overloading is set by a new constant, C_4 , which may be set by the agency.

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